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Poster paper

Development of a grazing-incidence insertion device X-ray beam position monitor at the Advanced Photon Source

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Beam stability is always a concern in synchrotron light source facilities, and accurate and stable X-ray beam position monitors (XBPM) are key elements in obtaining desired user beam stability. Currently, Advanced Photon Source is preparing to upgrade its facility to increase productivity and to provide better beam stability. For better beam stability, a grazing-incidence insertion device X-ray beam position monitor (GRID-XBPM) is proposed for the insertion device beamline front ends instead of the current photoemission-based XBPM. The design and development of the GRID-XBPM are summarized in this paper including the thermal simulation results of the GRID-XBPM. Thermal and stress analyses show that it withstands the 21 kW total beam power and the peak heat flux of 1684 W mm^{-2} at a grazing incidence angle of 0.80° using a heat transfer coefficient of 0.010 Wmm^{-2} °C^{-1}.

1. Introduction

The Advanced Photon Source (APS) is a 7 GeV third-generation synchrotron radiation facility that produces X-rays with very high brightness, power and flux over a wide energy range. Currently, two photoemission blade-based X-ray beam position monitors (XPBMs) are installed in each APS front end to monitor the vertical and horizontal X-ray beam by measuring photoelectrons generated by the sensory blades and deducing the beam position by comparison of the relative signals from the blades (Shu *et al.* 1992). However, the signals from the blades of the photoemission-type XBPM are sensitive to the insertion device gap changes because of contamination by the soft X-ray radiation photons emitted from nearby dipole, quadrupole and sextupole magnets. The ultimate goal at APS is to deliver a high degree of X-ray beam position stability to the users using feedback control to achieve AC displacement/angle beam stability at the level of 3.0 μm/0.53 μrad r.m.s. horizontally and 0.4 μm/0.22 μrad r.m.s. vertically within a frequency band of 0.017–200 Hz (Decker). The best way to accurately and precisely measure the beam centroid is to terminate the beam on Cu or its alloy and then use the

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emitted X-ray fluorescence (XRF) as a diagnostic tool. To implement the XRF-based XBPM in place of the present photoemission-based XBPM, a grazing-incidence insertion device X-ray beam position monitor (GRID-XBPM) geometry has been studied and is proposed for use in insertion device beamline front ends for the future APS upgrade. In what follows, conceptual designs of the GRID-XBPM for the APS upgrade and finite-element simulation results are presented.

2. Conceptual design

The maximum total power and the maximum power density of the current high heat load front end (HHL FE) of sectors 26 and 30 at the APS are limited to 21.0 kW and 590 kW mrad^{-2} at a grazing incidence angle of 0.86° (Jaski 2004). This front end allows the operation of two in-line 3.3 cm-period, 2.4 m-long undulators at $k = 2.76$ with 180 mA. Similar to the design concept of shutters and collimators applied to the design of APS HHL FE components whose exposure surfaces are vertically positioned to accept higher total power load, in the design of the GRID-XBPM, its active surfaces are vertically positioned and cut the beam at an angle of 0.80° (14mrad). For the calculation of the minimum length with a grazing incidence angle of 0.80°, we also consider dynamic range of the XBPM (±0.5 mm), tolerance of misalignment (±0.15 mm), and an additional 1.0 mm overlap section into the shadow at the far downstream end. Figure 1 is a detailed model that presents the overall length of 45.6 inches and the exit aperture of the GRID-XBPM, which has four 'fins' around the main beam path that can be used for

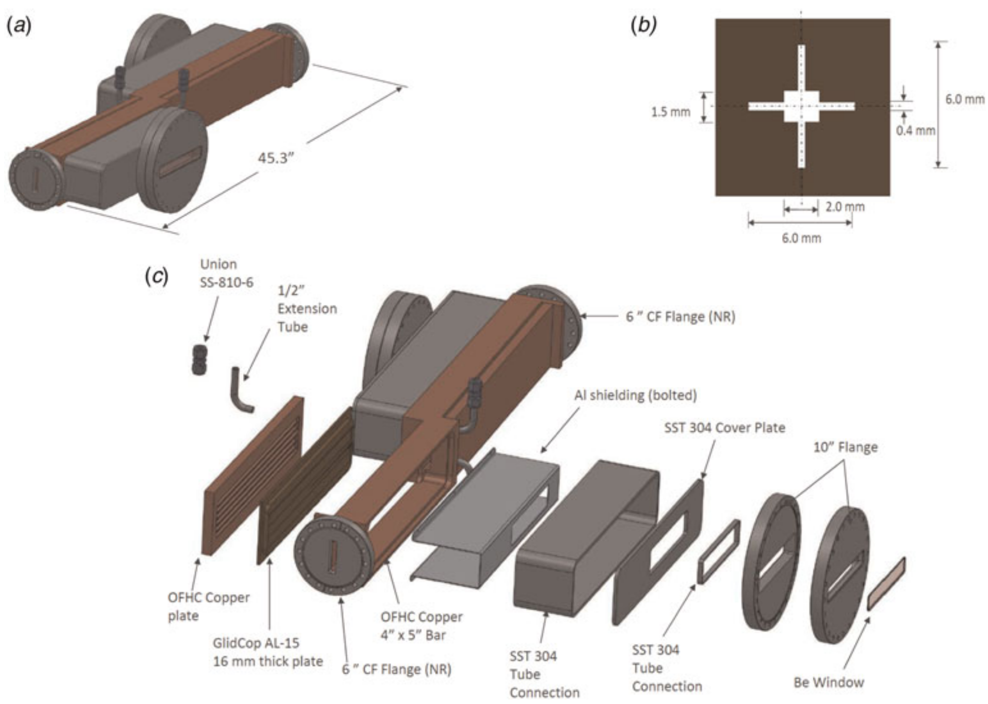

FIGURE 1. Overall dimension (*a*), exit aperture detail (*b*) and exploded view (*c*) of the GRID-XBPM.

pinhole-camera-like measurement of the electron beam source location measured using a detector positioned further downstream.

3. Numerical simulation

ANSYS 12.0 Workbench software was used for the finite-element thermal stress–strain analysis. Figure 2(*a*) shows the stress distribution over the GlidCop active surface. The temperature distribution is similar to the stress distribution. Figure 2(*b*) shows the temperature distribution over the cooling channel. Under normal operating conditions, the maximum cooling channel temperature, active surface temperature and Von-Mises stress can reach 77°C, 184°C and 296 MPa, respectively. Under the worst missteered conditions studied, they can reach 101°C, 229°C, and 384 MPa, respectively. These values are well within our engineering limits of 150°C, 300°C, and 455 MPa based on the APS thermal stress criteria (Jaski 2004). By assuming a linear pressure drop, we may add up to 28.4°C ($\Delta T \cong 21{,}310$ W/2.85 gpm/262.9) to account for the enthalpy rise of the fluid. Maximum temperatures, even in this case, are within the engineering limits at the 21 kW total beam power and the peak heat flux of up to 1684 W mm^{-2}.

4. Discussion

The conceptual design of the GRID-XBPM for use in the insertion device beamline front ends for the future APS upgrade was performed with a grazing incident angle of 0.80° (14 mrad). Thermal simulation results show that under the worst missteered conditions studied, they are well within the engineering limits. However, there is a natural response of surface deformation, called a thermal bump, that is caused by the thermal expansion of the active heated material in the direction perpendicular to the surface. This is undesirable in the XRF-based XBPM system. Also, due to its high heat load and overall length of 45.3 inches, 0.3 mm longitudinal displacement of the GRID-XBPM along the beam direction is expected, and slight bending and twisting in the main copper body due to its asymmetric design would be expected. For these reasons, care must be taken to allow longitudinal displacement to avoid any high-stress concentration points in designing its support structure. In conclusion, the GRID-XPBM can offer a potential solution to improve the beam positioning accuracy and stability for use in the HHL FE at the APS instead of using the current photoemission-based XBPM. In future work, we will work on geometric simplification of the GRID-XBPM by removing the fins around the main beam aperture and by reducing its active surface length.

(*a*) (*b*)

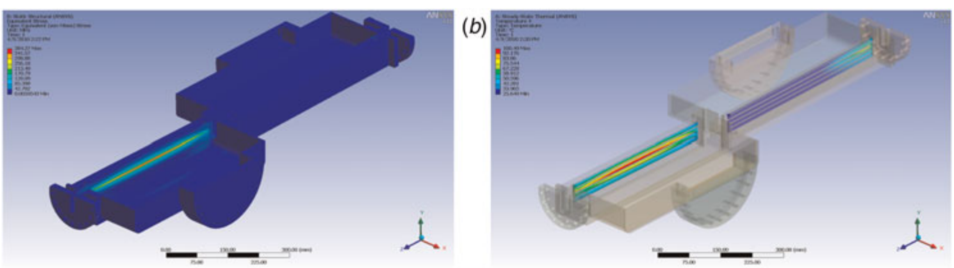

FIGURE 2. Stress distribution (*a*) and cooling channel temperature distribution (*b*).

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